Does transgenerational acclimation improve fish behaviour under elevated CO$_2$?

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www.coralcoe.org.au
Carbon Dioxide (CO$_2$)

- 280 ppm pre-industrial times -> 400 ppm today

IPCC 2014 Chapter 12: Long term Climate Change
Ocean Acidification

$CO_2 + H_2O \rightarrow HCO_3^- + H^+$

$H^+ + CO_3^{2-} \rightarrow HCO_3^-$

$CaCO_3 \rightarrow Ca^{2+} + CO_3^{2-}$ (coral)

Hoegh-Guldberg et al. 2007. Science
### Ocean Acidification

<table>
<thead>
<tr>
<th>Physiological Response</th>
<th>Major Group</th>
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<tbody>
<tr>
<td><strong>Calcification</strong></td>
<td>Coccolithophores¹</td>
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<tr>
<td></td>
<td>Planktonic Foraminifera</td>
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<td>Molluscs</td>
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<td></td>
<td>Echinoderms¹</td>
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<td></td>
<td>Tropical corals</td>
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<td></td>
<td>Coralline red algae</td>
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<tr>
<td><strong>Photosynthesis²</strong></td>
<td>Coccolithophores³</td>
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<td></td>
<td>Prokaryotes</td>
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<td></td>
<td>Seagrasses</td>
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<tr>
<td><strong>Nitrogen Fixation</strong></td>
<td>Cyanobacteria</td>
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<tr>
<td><strong>Reproduction</strong></td>
<td>Molluscs</td>
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<tr>
<td></td>
<td>Echinoderms</td>
</tr>
</tbody>
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Altered Behaviour

- Increase in activity levels
- Slowed visual acuity
- Loss of behavioural lateralization
- Altered auditory & olfactory preferences
- Result of impaired neurotransmitter function
Altered Behaviour

- CO₂ seep studies = impaired behaviour persists (Munday et al. 2014. Nature Climate Change)
Transgenerational Acclimation

- Environment experienced by parents influences offspring response to environmental conditions
Transgenerational Acclimation

- Parental environment ameliorates CO₂ stress
- No effects on offspring size or provisioning (maternal effects)

Miller et al. 2012. Nature Climate Change
Olfaction

- Present day control conditions $\rightarrow$ avoid predator & chemical alarm cue
Olfaction

- Present day control conditions → avoid predator & chemical alarm cue
Altered Behaviour: Olfaction

- Present day control conditions → avoid chemical alarm cue

- Under CO₂ → Attracted to predator cue and chemical alarm cue
  (Munday et al. 2009; Dixson et al. 2010; Ferrari et al. 2011)
Lateralization

- Present day control conditions → Minimal decision-making time
Altered Behaviour: Lateralization

- Present day control conditions $\rightarrow$ Minimal decision-making time

- Under CO$_2$ $\rightarrow$ Directionality disrupted: delayed decisions (Domenici et al. 2011)
Aim

Can transgenerational acclimation improve the negative consequences of CO$_2$ on olfactory and cognitive impairment?
Study Species

Spiny Chromis Damselfish - *Acanthochromis polyacanthus*

- Close relative of *Amphiprion percula* (previous acute $\text{CO}_2$ behaviour studies) & *Amphiprion melanopus* (transgenerational acclimation for life history traits)
Design

Parents

Offspring

Acute effects

Transgenerational acclimation

Carry-over effects

446 μatm

656 μatm

912 μatm

Control

Mid CO₂

High CO₂

Control

Mid CO₂

High CO₂

Control

Mid CO₂

High CO₂

Parents

Offspring

Transgenerational acclimation
Design

Olfactory Flume

Chemical alarm cue (CAC) vs. seawater

Cognitive Lateralization Chamber


Results: Olfaction

Parental treatment

- Control
- Mid-CO₂
- High-CO₂

Time spent in cue (%)

Welch et al. 2014 Nature Climate Change
Results: Lateralization

Welch et al. 2014 Nature Climate Change
Summary

- Impaired sensory & cognitive functions are NOT ameliorated by parental exposure to elevated CO$_2$.
- Attraction to chemical alarm cues $\rightarrow$ increase in mortality.
- Prolonged decision-making time near predators $\rightarrow$ increase in mortality.
Summary

- Most work to date = single generation
- Transgenerational restoration for life history traits under CO$_2$ (Miller et al. 2012)
- No transgenerational restoration for behavioural traits (Welch et al. 2014)
- Carry-over effects = performed worse
- Take a closer look at the pathways
Future Consideration

- Genetic adaptation will be necessary to overcome behavioural impairments
- Affect population dynamics and marine ecosystem functionality
Thank You!

Co-authors Phil Munday, Sue-Ann Watson, Justin Welsh, and Mark McCormick

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MARFU staff; Munday lab; McCormick lab